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Common Potato Diseases and their Control

BY

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INTRODUCTION

The potato, one of our most important food plants, is subject to many diseases. These are among the chief limiting factors in its production. It is rarely if ever possible to grow this crop without experiencing some damage from disease. Those who wish to obtain maximum returns from potato culture must give attention to disease prevention.

The potato grower in the prairie provinces of western Canada is fortunate in that his crops are safe from the ravages of late blight, probably the most destructive potato disease known. This, together with the fact that most districts of this part of Canada are free, or relatively so, from the Colorado potato beetle, removes the necessity in many areas of costly spraying practices, which the potato grower in eastern Canada finds imperative. This advantage is offset to a considerable extent by higher transportation costs due to our great distance from the larger centres of consumption.

There are, however, prevalent in western Canada a number of potato diseases which are a constant menace to the crop, and which seriously affect the yield and quality of the tubers. It is the purpose of this circular merely to describe a few of the more common diseases which occur here, and to suggest measures which may be taken to reduce losses from them.

DISEASES CAUSED BY MICRO-ORGANISMS

A number of kinds of both fungi and bacteria attack the potato and produce specific diseases. These may be recognized by characteristic symptoms produced, and by the micro-organisms associated with them. These disease organisms differ in their life histories and in other respects, and consideration must be given to such differences in devising preventive measures.

BLACK SCURF OR RHIZOCTONIA ✓

The Rhizoctonia disease is one of the most prevalent and destructive diseases of the potato. It is very common in Alberta. Black particles found on the surface of mature tubers, which resemble lumps of dirt, but which will not wash off, are evidences of the presence of this disease (Figure 1).

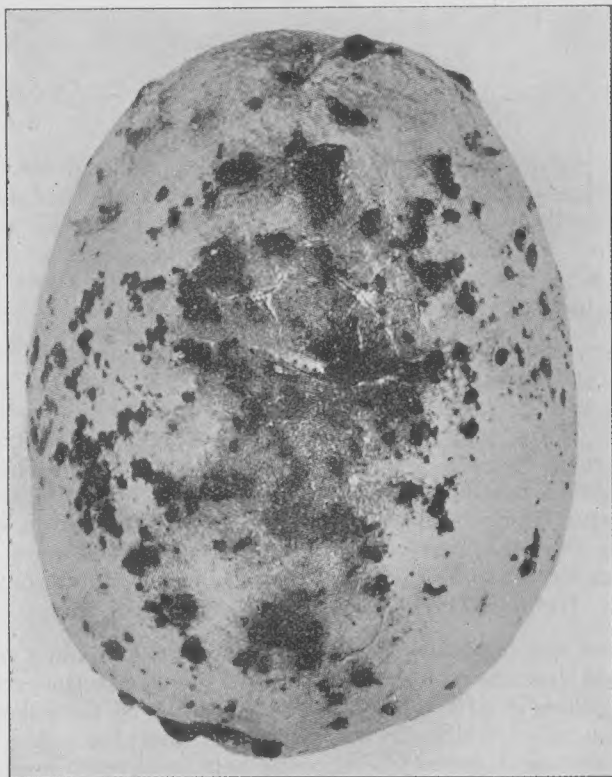


Figure 1.—Potato tuber affected with black scurf or Rhizoctonia. The black lumps are sclerotia of the causal fungus (after Morse and Shapovalov).

While these disfigure the tubers, they do not injure them greatly. The chief damage is done after sprouts are sent up following the germination of the tubers. These and other underground parts of the plant develop brown cankers (Figure 2), which often girdle the affected part. This may cause various abnormalities of the plant, resulting in serious reduction in yield if many plants are affected. When the main stem is severely cankered, the margins of the upper leaves

tend to roll inward and often develop a reddish tinge. Such plants are inclined to be stiff and upright in habit, and to remain so even after adjacent healthy plants have begun to ripen. They are usually yellowish and unthrifty in appearance. Very similar symptoms may be produced as a result of wireworm attack or other injuries, but in such cases the characteristic stem cankers of *Rhizoctonia* are lacking. Sometimes the water- and food-conducting tissues are damaged and cannot function properly. As a result small tubers may be formed on the tops. The development of the tubers below ground is often interfered with, so that small tubers result. Clusters of these the size of marbles are sometimes formed close to the main stem.

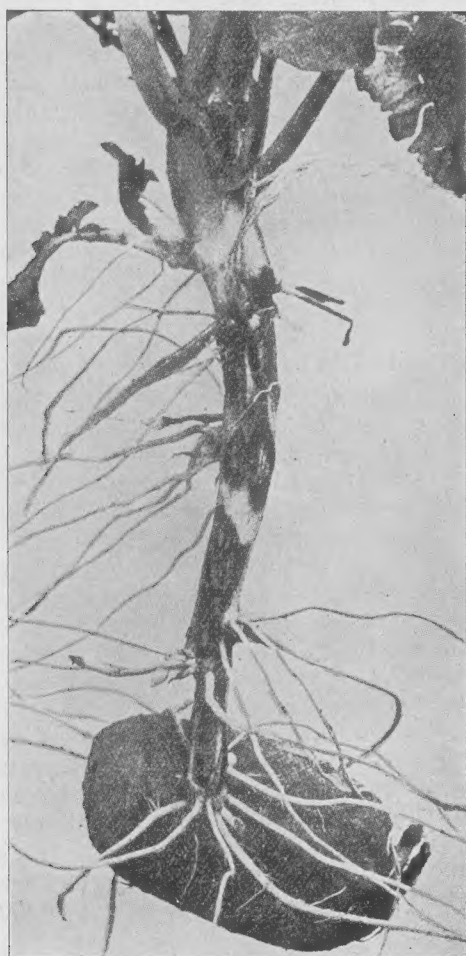


Figure 2.—Potato plant showing *Rhizoctonia* cankers on the stem (after McKay).

This disease is caused by a micro-organism belonging to the group of mold-like plants known as fungi. The small black lumps produced on the surface of potato tubers consist of dense masses of the vegetative strands of the fungus. These are dormant structures, and constitute one of the stages in which the organism is able to live over from one growing season to the next. They are able to resume growth when the tubers bearing them are planted, and a thread-like growth is developed which may invade the underground parts of the plant and produce the characteristic cankers of the disease. In addition to living a parasitic existence on the potato and certain other plants, this organism is able to live apart from the host plant in the soil itself. The vegetative strands of the fungus, like the underground part of a mushroom, seem able to live for extended periods in the soil. They may occur in fact in soils which have never borne a crop of potatoes. Furthermore, potato plants apparently often become infected from such soil-borne strands of the organism. It was thought for a long time that this fungus existed only in the vegetative stages just described, in which form it was known as *Rhizoctonia*. A fruiting or spore-bearing stage, however, is now known, and has been given the name *Corticium vagum*. This is the proper name now applied by scientists to the causal organism. The spores produced in this fruiting stage correspond to the seeds of higher plants. They are formed in a whitish growth at the base of stems of affected plants, just above the ground line. This stage, however, does not seem to be essential in the propagative life of the fungus.

In this disease, then, there are two main sources of infection: (1) the black bodies or sclerotia on the surface of seed potatoes, and (2) strands of the fungus or sclerotia in the soil, or on other susceptible plants besides the potato. The sclerotia on seed potatoes can be killed by the use of certain chemicals, and thus this important source of infection can be destroyed. Seed selection for freedom from sclerotia should of course always precede treatment. While seed treatment may be of value in controlling this disease, other sources of infection should not be disregarded. Since infection may come from contaminated soils, it is important to reduce this danger as much as possible. The most practical way of doing this is to practise a rotation in which potatoes are grown only once in several years on the same land. The more frequently potatoes are grown, the more badly is the land likely to become contaminated with the organism. Prompt digging of the potatoes may reduce the number of sclerotia formed on them, hence, where possible, delayed digging should be avoided.

COMMON SCAB ✓

Common scab is perhaps the best-known disease of the potato. It is a familiar disease wherever the potato is grown and used. Few lots of potatoes are free from the blemishes characteristic of this disease. These, as shown in Figure 3, consist of ruptured, corky spots scattered over the surface of the tubers. They detract from the appearance of the tubers, rendering them less saleable. In paring affected potatoes, considerable waste results due to the thicker peeling necessary. Scabby potatoes decay more readily than normal ones, as rot-producing organisms can enter the former more easily. They suffer more loss in storage and are less desirable for seed than normal tubers.

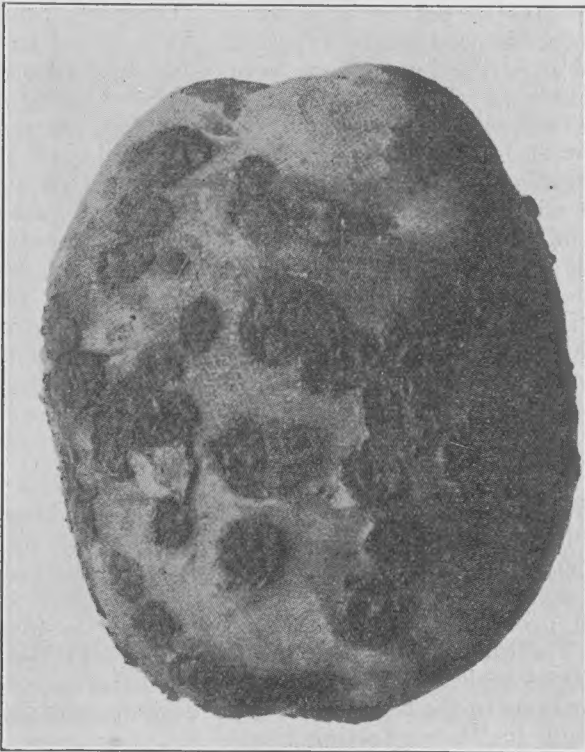


Figure 3.—Potato tuber affected with common scab (after Stakman).

The cause of common scab in potatoes is a micro-organism, known under the name *Actinomyces scabies*. The scabby spots on infected tubers contain the very fine thread-like organism.

The scab organism also occurs in the soil. Even virgin soils may contain strains of *Actinomyces* which are capable of producing scab in the potato. It is true that potatoes planted on scab-infested soils do not always become scabby. Certain environmental factors have an important relation to infection. If the soil, for instance, is wet during the early development of the tubers, they may remain free from scab, even though the soil be heavily infested. If, on the other hand, the soil is dry at this time, the tubers may be very severely attacked by the scab organism. Soil temperature and soil reaction also influence the amount of scab infection. It is well known, for instance, that alkalinity favors scab; hence lime or wood ashes added to land intended for potatoes, are likely to increase the severity of scab infection considerably.

Scab control is not an easy matter. Complete control by present methods need not be expected. As is shown in Tables I-III, and as Sanford and others have found, seed treatment of scabby tubers may have little or no effect in reducing scab in the subsequent crop. Treatment may be of value, where scabby tubers are used for seed, in preventing increased soil infestation, but many soils appear to be naturally infested and seed treatment will not prevent infection from soil-borne scab. Nor is it possible to rid the soil of the organism by rotation, but rotation is advisable as the severity of the disease is likely to be greater on land continually cropped to potatoes. Russet-skinned potatoes, though not so generally grown as smooth-skinned varieties, enjoy a much greater freedom from scab. Under some conditions control may be feasible by the treatment of the soil with chemicals.

BLACKLEG ✓

A black soft rot of the base of the stem is a characteristic of the blackleg disease, and from this it gets its name (Figure 4). Affected plants turn yellow and frequently fall over and die prematurely. The rot usually starts in the seed piece and proceeds up the stem to several inches above the ground. The tubers often become infected through the underground stems which bear them. Affected tubers may rot in the soil or later in the bin. There may develop, however, only a black ring in the conducting tissues at the stem end of the tuber. Such infected tubers, if used for seed, may transmit the organism to the next crop. The causal organism, a bacterial parasite, *Bacillus carotovorus*, is also known to live over



Figure 4.—Blackleg of the potato (after McKay).

winter in the soil, and healthy seed pieces may become infected from this source. An insect known as the seed-corn maggot is also able to inoculate seed pieces, after becoming contaminated with the organism. The seed piece is able to ward off infection under certain conditions, by the formation of corky layers of cells, but in wet soils, where the air supply is poor, they may not be able to do so. Under such conditions severe

damage from blackleg is likely to occur. The disease has been noted by Marritt to develop readily also in sandy soils in northern parts of Saskatchewan and Alberta.

Treatment of seed tubers, at least in some experiments, has reduced the percentage of blackleg plants in the resulting crop and the early decay of seed pieces. Certain preparations, in which mercury is the toxic agent, appear to be of especial value for purposes of treatment. It is of considerable importance in the control of this disease to select the seed stock carefully from healthy plants, to discard at cutting time any tubers which show internal discoloration, and to plant as soon as possible after cutting the seed pieces. It is also advisable to avoid for potato planting, fields or parts of fields which are likely to be water-logged or very wet after the crop is planted. If such soils are used, shallow rather than deep planting should be practised.

GENERAL CONTROL MEASURES

Seed Selection

Many of the micro-organisms causing potato diseases are seed-borne, or rather tuber-borne. It might therefore be expected that the selection of clean, healthy-appearing tubers would be of value as a general preventive measure. This is quite true, and is one reason for the superiority of "Certified Seed" over ordinary seed. Selection of seed from apparently healthy plants, coupled with bin selection of clean-appearing tubers, is undoubtedly advisable from the standpoint of disease control. At the same time, it should be recognized that this does not necessarily insure a clean bill of health for the subsequent crop. Reasons for this are quite apparent. One reason is that some of the selected tubers may be internally diseased and this may not be detected. Another and more weighty one is that inoculum from other sources, for instance from the soil or crop residues, may be of more importance than that carried by the tubers.

Seed Treatment

Value of seed treatment.

Treatment of seed tubers is practised chiefly to kill inoculum of disease organisms present on or near the surface of the tubers. As already noted, inoculum is commonly tuber-borne in each of the three diseases which have been described; and in two of them, namely black scurf and common scab, it occurs on or near the surface. In blackleg it is frequently

inside of the tuber. In all three diseases inoculum is also commonly soil-borne, so that seed treatment is unlikely to result in complete freedom from these diseases.

Seed treatment is likely to prove most effective in reducing damage from black scurf. If diseased tubers are used for seed, seed treatment may appreciably reduce the severity of infection and increase the yield of marketable tubers, as indicated by the results in the following tables. The principal beneficial effect so far as black scurf control is concerned is due to a reduction in amount and severity of stem cankers. These apparently commonly arise from seed-borne inoculum when diseased sets are used. Stem infection is much the more serious form of the disease, since it has the principal effect on yield, whereas tuber infection merely influences quality.

Common scab affects the tubers chiefly, and appears to be reduced little if at all by seed treatment (Table III). If seed treatments are of any value in respect to common scab, their value would seem to consist chiefly in the prevention of infestation by seed-borne inoculum of soils which are relatively free from the causal organism.

No data concerning the effect of seed treatment on the control of blackleg are given, but seed treatment, as a preventive measure, is recommended by others who have studied the disease. By killing surface-borne bacteria and reducing seed piece decay, seed treatment seems to be of some value in blackleg prevention and may be warranted in areas where conditions are favorable for the disease, and where unselected seed is used.

It is evident that the value of seed treatment in general will depend on the nature of the seed sown, and on the soil and other conditions under which the crop is grown. If the soil, for instance, is heavily infested, seed treatment may not be advisable. Our experimental results, however, indicate that it was of value under our soil conditions at Edmonton when the tubers used for seed were affected either lightly or heavily with black scurf. However, in the absence of black scurf, it remains doubtful if seed treatment would be warranted from the standpoint of immediate financial returns. If clean, certified seed is used, seed treatment may be unnecessary.

Methods of Seed Treatment.

Judging from the results of our tests, the standard mercuric chloride treatment has proved most consistently effective in the prevention of black scurf. This method is rather time-consuming, however, and where large quantities of tubers are

TABLE I.—Results of Treatments of Seed Potatoes for the Control of Black Scurf and Common Scab in 1930.

Treatment	Yield of marketable tubers Bus. per acre	Scab on tubers		Black Scurf on tubers		Black Scurf on stems	
		% Infection	% Degree Infection	% Infection	% Degree Infection	% Infection	% Degree Infection
Untreated—Check	238	46.0	10.8	68.0	18.4	89.0	47.6
Mercuric chloride, 4 oz.+25 gals. water, 1½ hr. soak	264	68.0	20.0	14.0	4.0	51.0	19.4
Acid-Mercury Dip, Mercuric chloride, (1-500)+1% hydrochloric acid, 5 min. soak	270	50.0	12.4	38.0	9.8	56.0	27.2
Formaldehyde—cold, 1 pint+30 gals. water....	268	65.0	17.2	38.0	10.2	56.0	20.0
Formaldehyde—hot, 51°C. for 3-4 min.....	265	44.0	9.8	49.0	13.2	66.0	29.0

TABLE II.—Results of Treatments of Seed Potatoes for the Control of Black Scurf and Common Scab in 1931.

14 Badly Diseased Tubers:							
Untreated—Check	359	44.0	9.6	9.0	2.4	89.0	31.0
Mercuric chloride, 4 oz.+25 gals. water, 1½ hr. soak	437	38.0	7.6	9.0	1.8	56.0	15.6
Acid-Mercury Dip, 10 min. soak	396	26.0	5.2	10.0	2.0	69.0	15.0
Improved Semesan Bel 927, 1-lb.+7½ gals. water, 1 min. soak	350			8.0	1.6	96.0	34.3
Du Bay 965L, 1-lb.+7½ gals. water, 1 min. soak	425	49.0	10.6	1.0	0.2	54.0	14.8
Lightly Diseased Tubers:							
Untreated—Check	391	36.0	7.4	4.0	0.8	85.0	26.6
Mercuric chloride, 4 oz.+25 gals. water, 1½ hr. soak	487	39.0	9.0	5.0	1.0	55.0	11.8
Acid-Mercury Dip, 10 min. soak	402	27.0	6.0	12.0	2.4	72.0	16.0
Improved Semesan Bel 927, 1-lb.+7½ gals. water, 1 min. soak	443	30.0	6.0	8.0	2.0	62.0	18.6
Du Bay 965L, 1-lb.+7½ gals. water, 1 min. soak	461	33.0	6.8	12.0	2.4	48.0	11.2

TABLE III.—Effect of the Treatment of Seed Potatoes¹ with Mercuric Chloride² in 1929, 1930 and 1931 on yield and on the control of Black Scurf and Common Scab.

	1929		1930		1931		Average for 3 years	
	Mercuric chloride	None	Mercuric chloride	None	Mercuric chloride	None	Mercuric chloride	None
Yield of marketable tubers in bushels per acre.....	244	219	264	238	437	359	315	272
%% infection of stems with black scurf.....	24.8	46.8	51.0	89.0	56.0	89.0	43.9	74.9
%% degree infection of stems with black scurf.....	9.5	22.7	19.4	47.6	15.6	31.0	14.8	33.4
%% infection of tubers with black scurf.....			14.0	68.0	9.0	9.0	11.5	38.5
%% degree infection of tubers with black scurf.....			4.0	18.4	1.8	2.4	2.9	10.4
%% infection of tubers with common scab.....	82.8	92.0	68.0	46.0	38.0	44.0	62.9	60.7
%% degree infection of tubers with common scab.....	26.5	27.9	20.0	10.8	7.6	9.6	18.0	16.1

¹Tubers used were in all cases badly diseased with black scurf, and moderately so with common scab.

²In all tests the potatoes were soaked 1½ hrs. in a solution consisting of 4 oz. of mercuric chloride to 25 gals. of water.

to be treated quicker methods may be preferred. Wheeler and Moore found a $\frac{1}{2}$ - instead of a $1\frac{1}{2}$ -hour soak quite effective. A modification of the cold mercuric chloride method, known as the acid-mercury dip, as used in our 1929 and 1930 tests, was much more rapid and still reasonably efficient. Some of the commercial organic mercury preparations are still more rapid, but are liable to be costly. One preparation tested in 1931, and designated as Du Bay 965L, compared favorably with the standard mercuric chloride method.

While the chemicals containing mercury are usually preferred for the treatment of seed potatoes for the control of black scurf and blackleg, formaldehyde may be more convenient to use. In fact, in our tests the formaldehyde treatments have given results which compare very favorably with the mercury treatments. The hot-formaldehyde treatment is the more rapid of the formaldehyde treatments, but otherwise has shown little if any advantage in our tests.

Preparation and Application.

Standard Mercuric chloride (corrosive sublimate). The standard corrosive sublimate or mercuric chloride solution is made up by adding 4 ounces of the crystals to 25 gallons of water. It is advisable to dissolve the crystals first in a little hot water and then add this solution to more water to make up the 25 gallons. This quantity is sufficient to treat about 25 bushels of loose potatoes. The tubers should be soaked in the solution for $1\frac{1}{2}$ to 2 hours. After treating each 4 bushels of tubers $\frac{1}{2}$ ounce of corrosive sublimate crystals should be added to the solution until about 6 lots have been treated. The solution should then be discarded entirely and a new one made up, if more tubers are to be treated. Since delay in germination sometimes results from the treatment it has been found that this may be avoided by treating at least a month previous to planting. It is usually best to treat before cutting. If cut tubers are treated, it is well to renew the solution more frequently, as cut tubers weaken the solution much more rapidly than uncut tubers.

This chemical is a deadly poison, hence potatoes treated with it are unfit for food. As it corrodes metals, the containers used should be wooden, earthenware, concrete, or of some non-metallic material. Sacks should not be employed, as they weaken the solution by absorbing the chemical. If the tubers are dirty, it is advisable to wash them clean before they are treated, as the dirt also absorbs the chemical and therefore weakens the solution.

Acid-Mercury Dip. The following directions for this treatment with slight modifications are taken from Minnesota Circular 35, written by J. G. Leach and R. C. Rose:

Add 7 ounces of mercuric chloride to one quart of commercial hydrochloric acid (muriatic acid). It will dissolve in a few seconds.

Measure out 21 gallons of water in a non-metallic container (wooden barrel, tub or concrete tank). A metal container may be used if thoroughly painted inside with heavy asphaltum paint. The solution will corrode metal.

Pour the quart of acid containing the mercuric chloride into the water and mix thoroughly. The solution is now ready for use.

Dip the potatoes in this solution and allow them to remain for at least five minutes. If there are many large sclerotia (black bodies) on the tubers they may be soaked longer. Soaking 40 minutes will not injure the tubers.

A wooden crate, or a wire basket thoroughly painted with asphaltum paint, should be used for dipping the potatoes.

It is better to treat before cutting, although the tubers may be treated after cutting if desired. In this case, they should be planted the same day they are treated.

Twenty-one gallons of the solution is enough to treat about 34 bushels of potatoes, after which it would be well to prepare a new solution.

Unless the tubers are planted immediately, they must be spread out to dry. *Do not store treated potatoes while they are wet.* This is likely to injure them.

The diluted treating solution is not strong enough to injure the hands in ordinary practice. The strong acid should, however, be handled with care.

New chemicals. Directions for applying commercial preparations for seed treatment, such as the organic-mercury dips, are given on the containers in which they are sold.

Hot formaldehyde. Although the hot formaldehyde treatment is a quicker method than the cold corrosive sublimate treatment, it requires more care and more equipment. The solution used is made by adding 2 pints of commercial formaldehyde (formalin) to 30 gallons of water. This solution is heated up in a tank to 124°-126°F. and the potatoes are then dipped in this hot bath for 3 to 4 minutes. An accurate thermometer, such as a good floating dairy thermometer, is necessary, as the temperature must be accurately controlled and must not exceed 126°F. The equipment for heating the solu-

tion need not be elaborate or expensive. Satisfactory results may be obtained with a hog-scalding tank having a tin bottom, the heat being supplied by a wood fire built under the tank. In some districts it is possible to establish seed-treating centres at creameries or other plants where steam is available to heat the solution. Wire baskets are convenient for dipping purposes. If many potatoes are treated, or if the temperature rises too high, more solution will have to be added. A stock solution of the formalin and water mixture should be kept on hand for this purpose. After removal from the solution the treated potatoes should be covered with wet sacks for one hour and then dried. Since delayed sprouting sometimes results from this treatment also, this may be guarded against by treating a month or more before planting.

Cold formaldehyde. This treatment has a number of advantages for the grower who plants only a small quantity of potatoes each year. The solution used consists of 1 pint of formaldehyde to 30 gallons of water, and does not weaken with use. The tubers are soaked for $1\frac{1}{2}$ hours in this solution. Treated tubers are not poisonous. Hence they may safely be used for food if more than the desired quantity needed for seed is treated. Moreover, any kind of containers may be used, as the solution does not corrode metals.

Soil Treatment

It has already been mentioned that the soil is an important source of inoculum in the diseases which have been described, especially in common scab and black scurf. Obviously it would be desirable if this inoculum could be rendered harmless by some method of soil treatment.

Several methods of soil treatment have been tried with varying success in different places. The plowing under of a green crop, such as rye or a legume, just previous to planting potatoes has been reported to give protection, especially from common scab, in some tests but not in others. This practice might be used in the moister parts of western Canada, but would probably be unsuitable for the drier areas.

The application of sulphur to the soil has reduced the severity of scab in some soils, but has been found by J. D. Newton to be impractical for soils as alkaline as many of those in western Canada. The quantity of sulphur necessary to increase the acidity of the soil sufficiently to control scab, is too great to make the treatment economical for the majority of our soils.

Recently considerable success in the control of common scab and black scurf has been obtained by the application to the soil of toxic substances similar to those used in seed treatment. Among the most effective so far reported are mercuric chloride and calomel. Applications of these chemicals in dry form at the rate of 10 to 15 pounds per acre has been reported by MacLeod and Howatt to give effective control of common scab and black scurf in heavily infested soils. The chemicals were mixed first with inert dusts (1 part to 4 parts of dust) in order to permit more even distribution. This was then thoroughly mixed with the soil in which the tubers were to develop. The method as outlined causes a slight reduction in yield and, at present prices, is rather costly; but these objections may be overcome with further experimentation and if the demand for the chemicals increases sufficiently.

Crop Rotation

Potatoes, like other crops, should not be planted in soil which produced the same crop the previous year. The land should be planted to another crop or crops, or summerfallowed, before potatoes are grown again. At least a three- or four-year rotation should be followed. This will not control infectious diseases entirely, but it should help to reduce their severity; and is desirable in other respects as well.

DISEASES CAUSED BY VIRUSES

This group of potato diseases, sometimes referred to as the degeneration disease group, is a very important one, and one chiefly responsible for the so-called "running out" of potatoes. These diseases are caused by infectious principles which are invisible even with the aid of a microscope, and are termed viruses. Different viruses have different effects on the potato plant, resulting in symptoms by which the diseases are recognized. A virus once introduced into a plant tends to spread to all parts of the plant, and to be transmitted to the next crop by means of the tubers. The most common other method of transmission is from plant to plant in the field by means of certain insects, especially aphids. Numerous virus diseases of the potato are now known, but only a few of the more common ones will be described here.

MOSAIC DISEASES

Several of the virus diseases of the potato are characterized by a mottling of the foliage, and are consequently termed

mosaics. Mild mosaic, rugose mosaic, crinkle mosaic and leaf-rolling mosaic are diseases of this type. The first two are widely prevalent and are readily distinguished, as will be evident from the following descriptions.

Mild Mosaic. As might be judged from the name, this disease is characterized by less pronounced symptoms than most of the other mosaic diseases. The disease is most readily detected during cool weather and may be completely masked during warm weather. The leaves of affected plants under favorable conditions develop a mottled appearance, due to the formation of pale areas here and there in the blades of the leaflets (Figure 5). This may be accompanied by a small

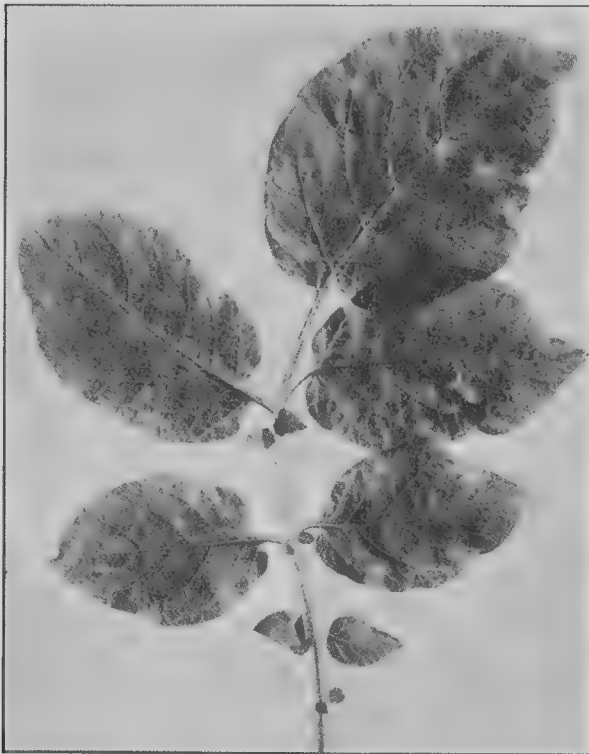


Figure 5.—Mild mosaic symptoms in a Green mountain leaf (after Schultz, Bonde, and Raleigh).

amount of crinkling and ruffling of the leaflets, and some dwarfing of the plant as a whole. The tubers of a diseased plant are indistinguishable from healthy tubers. The disease, however, causes a reduction in the average size of tubers and may lower the yield from twenty to thirty per cent. The disease is apparently caused by two viruses, one of which is transmitted from plant to plant in the field by aphids, and from one crop to the next by the use of diseased tubers for sets.

✓ *Rugose Mosaic.* This is a more destructive form of mosaic than mild mosaic. Plants arising from diseased sets are usually much stunted and their leaflets show pronounced crinkling. Instead of being flat as in normal leaves, the blades of the leaflets have very uneven surfaces, and in cool weather show a type of mottling in which the spots are small and numerous (Figure 6). The veins on the lower surfaces (especially those of basal leaves) of the leaflets may develop black streaks due to localized killing of the tissues.



Figure 6.—Rugose mosaic of Burbank potatoes. a, diseased; b, healthy (after McKay and Dykstra).

Recent investigations indicate that rugose mosaic is caused by a combination of two viruses, one normally present in apparently healthy potatoes, and not transmitted by aphids; and another, which is readily transmitted by aphids. Plants inoculated with the latter may develop symptoms the same season or may fail to do so. Such symptoms as do develop

are less striking than those of plants from diseased sets. They consist usually of irregular dead or burned areas beginning in the veins and extending into adjacent leaf tissues. The leaves in the central part of the plant most commonly develop these symptoms, and later these may die and droop or drop off. The leaves at the top of the plant may develop the characteristic mottling and crinkling symptoms. Tubers from diseased plants become infected, and if planted the following season will produce plants exhibiting the severe form of the disease previously described, and dying prematurely.

Rugose mosaic causes a marked reduction in number and size of tubers, the yield frequently being reduced to one-half or two-thirds of that of healthy plants.

✓ LEAF ROLL

In this virus disease the most prominent symptom is an upward rolling of the leaflets (Figure 7). This begins in the lower leaves in plants from diseased tubers, later extending to many of the other leaves. A paling or yellowing of the leaves is also typical—as well as a tendency to become stiff and brittle. An



Figure 7.—Leaf roll in the variety Early Ohio (after Murphy).

erect upright habit of growth is also usually characteristic of diseased plants. Affected plants are commonly distinctly stunted, the stolons bearing the tubers are usually short and the interior of the tubers often show a brown netting termed net-necrosis. The virus is apparently spread principally by aphids in the field. Plants which develop current season infections usually show leaf-rolling and yellowing at the top of the plants first.

If preventive measures are not taken, affected stock may become worthless in two to four years. The severity of the disease so far as yield reduction is concerned is similar to that of rugose mosaic.

WITCHES'-BROOM

Tubers infected with the witches'-broom virus produce weak, spindly sprouts. Numerous shoots develop from these, but fail to reach normal size, remaining slender and weak, with poorly developed leaves, the whole forming a broom-like bushy type of growth (Figure 8). The tubers are produced



Figure 8.—Witches'-broom in the variety Bliss Triumph. Left, diseased; right, healthy (after McKay and Dykstra).

in large numbers by diseased plants, but most of them are so small as to be unmarketable. If such tubers are used for seed, the crop from them is likely to be worthless. It is evident therefore that if this disease were to become at all abundant in a field, the effect would be very serious.



CONTROL OF VIRUS DISEASES

It has been pointed out that viruses of the potato are commonly transmitted from one crop to the next in the tubers. Since no method of seed treatment has been found which will destroy viruses inside of the tubers without injuring the tubers, methods must be adopted to prevent the infection of tubers intended for seed. This may be accomplished with considerable success by thorough field eradication or rogueing of diseased plants, and by the saving of seed tubers from apparently healthy plants only.

In rogueing it is important to remove diseased plants entirely, so there will be no danger of regrowth. Such plants should be placed in bags and removed from the field. It is not sufficient to do this for one year, but it is essential to continue the process year after year. Any potatoes which are offered for sale as seed in Canada must, according to law, have passed through such a process of selection. They are known as "Certified Seed," which means they have been inspected, both in the field and in the bin, by officers of the Dominion Division of Botany, and have been found to measure up to high standards of freedom from disease of all kinds, and to be good in other respects as well. Any one who is starting in to grow potatoes, or who is changing seed, should use "Certified Seed." Moreover, the grower who wishes to maintain or to improve the vigor of his own stock, may also profitably practice preventive measures for virus diseases.

• *Maintenance of a Seed Plot.* If several acres of potatoes are planted each year, the grower will be well advised to grow his seed potatoes in an isolated plot, some distance from his main crop of potatoes. This seed-plot should be about one-tenth the size of the acreage to be planted the following year. In planting it, selected tubers typical of the variety should be used, and these should be planted by the tuber-unit method, i.e., by sowing the sets from each tuber in succession, leaving spaces between the different tuber units. This makes possible more thorough rogueing of the field when the plants come up, than is possible if planted in the ordinary way. If disease or abnormal characteristics appear in a tuber-unit, all plants of that unit are discarded whether they show the abnormality or

not. Furthermore, the tuber units stand out much more clearly than an individual plant. This is particularly true if affected with virus diseases. Enough of the best plants are reserved to provide seed for the following year's seed plot, and the remainder furnish seed for the main crop.

The above method should be sufficient to keep virus diseases reasonably well under control, though it may not eliminate them entirely.

Special Methods for Certified Seed Growers. More specialized methods may be utilized by the grower of certified seed. He may, for instance, have his seed tubers for his seed plot tested before planting, by either the hill-indexing or the tuber-indexing method. In the former the potatoes from each hill are kept separate until tested for disease by growing a plant from one of its tubers, in a greenhouse. Any hills showing disease in this test are discarded. This method has not proved thoroughly reliable, due to the fact that in late infections only a portion of the tubers of a given hill may become infected. In the tuber-indexing method each tuber intended for seed is tested in a similar way by taking a small plug containing an eye from each tuber, and growing a test plant from it. Only tubers yielding healthy plants are then used for seed. Such methods, however, are too involved for the average grower, and are hardly warranted.

General Field Rogueing. Even though a seed plot is not maintained, field rogueing will be of some benefit. It is true that individual diseased plants are sometimes difficult to detect, but a considerable percentage will be noticed, and if these are removed, degeneration of the stock will at least be retarded. Where only a small garden plot of potatoes is planted each year, as is the case on the majority of farms, this could readily be planted by the tuber-unit method and the rogueing thus made easier and more thorough. If one plans on using his own seed each year, some such plan should be followed.

Resistant Varieties. There is some promise of controlling virus diseases of the potato by the use of resistant varieties, as recent work by members of the United States Department of Agriculture has demonstrated. Two varieties have been developed which are resistant to the mild mosaic virus. These varieties which have been called Katahdin and Chippewa are not available for general distribution as yet, but are being multiplied and tested further. Resistance to other mosaics has also been detected.

